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RFID Technology Applications with PMIS for Managing RMC Truck Operations

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Abstract

This research presents a strategy and information system to manage the logistics of delivery ready mixed concrete (RMC) under the integrated environment of PMIS+RFID. PMIS is system tool and technique used in construction sectors to delivery information. Information that can be extracted electronically in real time is more valuable than data gathered and maintained manually. RFID technology can help to improve data accuracy through supply chains and by identifying products and objects at specific points through automatic identification. The objectives of these two implementations can be able to improve the efficiency of logistics management for RMC truck process, and to verify the technical and practical feasibility of PMIS+RFID application in construction industry. This may be realistic given the dynamics of daily activities on construction sites. This research is focused on examples on real world case study, applications and research theme related and connected to PMIS+RFID technology. It demonstrated that PMIS+RFID technology has been automatically implemented and has shown process information about the RMC truck and the overall status information about it, both quickly and accurately. As a result, the construction site where needs 300 ㎥ pouring (50 RMC trucks) per day can be reduced total 250 minutes. Moreover, this time saving is related to the labour cost saving. From the case studies, RFID+PMIS system was proven in terms of effectiveness rather than current method.

Keywords : radio frequency identification, project management information system, ready mixed concrete

1. Introduction

Supply chain management (SCM) of construction material delivery is one of important key to a successful construction project. Along with the development of the SCM for the construction industry, as one of the key operations within the SCM, an efficient ready mixed concrete (RMC) delivering process becomes important to the RMC batch plant[1]. RMC is an essential material in contemporary construction and engineering projects, and thus it is imperative that the process of acquiring and handling RMC is managed with the utmost efficiency and accuracy[2]. However, RMC plants do not find it easy to match the timing of RMC trucks deliveries with the needs of the sites they serve.

Project performance data in the construction supply chain are commonly collected using traditional manual methods. The integrated RMC trucks' control is found reliable and accurate for recording key event times of the RMC truck under practical site conditions as well. Especially, RMC truck process models have been proposed as effective alternatives to the support of decision making. It is a common construction processes in a very wide range of construction projects. Several researches have demonstrated potential applications of RMC truck process in construction projects. Wang et al. [3] developed a simulation model that found out the best arrival pattern of RMC trucks. Feng and Wu[1]

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developed a systematic model incorporating the fast messy genetic algorithm and the CYCLONE simulation technique to find the optimal dispatching schedule. Graham et al.[2] determined whether or not feed-forward artificial neural network models were capable of accurately modelling the RMC delivery model to allow productivity and cycle time estimates of the process to be established. Yan and Lai[4] presented a new model that integrated RMC production scheduling and truck dispatching into the same framework to decide on an optimal RMC supply schedule with overtime. Most of mentioned previous researches into RMC truck operations have mainly focused on the production process or the dispatching process. Unfortunately, these developed models are too difficult to solve systematic optimization approaches such an integrated problems on construction site. Also, most of RMC trucks still handle RMC production scheduling and dispatching manually based on project managers' experience. This may not be realistic given the dynamics of daily activities on construction sites. These methods are neither efficient nor effective and not considered practical in a real-world construction applications since developing models to apply in construction industry. Limitations in data transfer among on head offices, construction sites, subcontractors, and classic database result in lower data quality, longer service process times, and ineffective capturing of information of data. The computer integrated previous developed models are unable to provide detailed RMC truck time information as well. However, control of these operations requires the more reliable information system. To address these difficulties, this research applies advances in a computer and information technology (IT), project management information system (PMIS), and using radio frequency identification (RFID) technology to minimize the problems and risks in the SCM of construction industry.

The research interest in developing PMIS and RFID hardware device technology, system has been rapidly growing in recent years. PMIS is system tool and technique used in construction sectors to delivery information. Project managers use the techniques and tools to collect, combine and distribute information through electronic and manual means [5]. RFID technology in the construction industry has been made gradual progress even through lack of standardization and skilled labour, high costs of implementation, and necessity of new automatic technologies. The RFID is an automatic identification technology that relies on radio frequency (RF) waves to read encoded digital data. This technology enables the detection and identification of tagged objects through the data it transmits. This would have the effect of reducing costs on each project in the construction sector as a whole[6,7]. The RFID technology can help to improve data accuracy through supply chains and by identifying products and objects at specific points through automatic identification. It provides an opportunity to meet the current needs for communicating RMC truck information on PMIS database, and accessing this information on-demand as well.

This research presents a strategy and information system to manage the logistics of delivery RMC under the integrated environment of PMIS+RFID. Therefore, this research develops RFID+PMIS based logistics of delivery RMC by case study. After confirms improvement of smooth information flow and least problem, then this research tries to evaluate reliability and feasibility of this system based on the time reduced result. The developed system can be easily collected through RFID hardware device technology and be input to the PMIS environment. The PMIS has been developed to test the applicability of RFID hardware device based

monitoring in the RMC truck process. Data and information associated to a RMC truck are carried by the RFID tag invoice and can be handled to manage the whole process. The time associated data of RMC trucks from the RMC plant to the construction site are automatically generated status of the progress of RMC trucks into PMIS database. This research is focused on examples on real-world case study, applications and research themes related and connected to PMIS+RFID technology in construction industry. It demonstrated that RFID+PMIS technology can improve the accurate of data communication in the RMC truck process.

The reminder of this research is organized as follows: First, the literature review of RFID applications in construction industry is done, and then limitations of them elaborated on data communication. The review of RFID technology is presented, followed by its usage within utility conditions. In the following section, the case study of RMC truck process experiment results from a construction site is presented to demonstrate the usefulness of applied system, with respect to: (1) analyzing PMIS+RFID technology based RMC truck process of autonomous data collection on real-world construction site; and (2) Monitoring the process of RMC trucks using PMIS+RFID technology. A discussion of potential applications and a description of the case study of a real-world construction project are provided. Conclusion is drawn and future research recommendations made in the end.

2. Previous RFID Applications in Construction Industry

RFID is a proven technology that is being widely used in many sectors other than construction industry. The RFID technology is currently being used in such sectors as agriculture, athletics, manufacturing, security and law enforcement, and transportation, but few applications have been developed that are related to the construction industry, such as concrete operation, labour management, productivity analysis, construction tool tracking, and pipe spool tracking[6-13]. These applications are developed using RFID tags which can store a certain amount of data. Jaselskis et al.[6] provided a description of RFID technology and potential applications in the construction industry. Jaselskis and El-Misalami[7] investigated RFID's technological functionality for materials tracking as well. Navon and Goldschmidt[8] developed general project control issues and describes the development of labor-input monitoring model based on automated data collection. Choi[9] showed RFID system's case study and its possibilities of future directions in A/E/C industry. Song et al.[10] presented an approach by which RFID technology is demonstrated to be feasible in determining the 2D location of materials, without modifications to current hardware and potentially at a magnitude of less cost than pure global positioning system (GPS). Goodrum et al.[11] examined a spectrum of RFID systems in the development of a tool tracking prototype for the construction industry. Ergen et al.[12,13] identified how RFID technology can improve current facility management processes, and to determine technological feasibility and reliability of using RFID within a facility on a daily basis for facility management processes, and a GPS was used to track and locate components in a precast concrete storage yard.

Based on these researches, it appears that RFID is a promising technology as it related to construction industry. There has been a lack of instruction on how it can be exactly applied to real-world construction projects, even if many

researchers have been performing feasibility studies of RFID applications in construction industry. On the other hand, the real time monitoring system was developed by combining the RFID hardware devices and a web-based software program demonstrated that the associated project of managers and engineers can access the detailed information anywhere at anytime by simply setting up the readers and antennas over the wireless internet.

3. RFID in General

RFID technology is becoming more popular nowadays. Some of the benefits can also be achieved already through better use of current barcode systems. Barcode and RFID are quite similar since both provide rapid, reliable item identification and tracking capabilities. However, RFID is overcome the limitation of barcode technology. The primary difference is that barcode scans a printed label with optical laser or imaging technology, while RFID scans a tag using RF. The data capacity of the RFID tags enables it to carry more information than the barcode.

Table 1. Barcode versus RFID technology

Item	Barcode	RFID
Speed	One at a time	Multiple at a time
Range	< 6 meters	< 180 meters
Visibility	Line of sight	RF transparent materials
Implementation	Easy	Challenging
cost	Low to medium	Medium to high

In addition, the barcode is much more fragile because fluids and rough handling may destroy the readability. Still, barcode cannot offer all the advantages achievable with RFID. RFID refers to a branch of automatic identification technologies in which RF are used to capture and transmit data[7]. Table 1 shows a high-level overview of the five comparisons made earlier a barcode and RFID.

The concept of RFID working process is simple. RFID uses RF waves instead of light waves to read a tag. The technology of RFID is that connects objects to internet and databases, so it can be tracked or identified, and associated project managers and engineers can share data. RFID system is composed of a reader, a tag, and a predefined protocol definition for the information transferred as shown in Fig. 2.

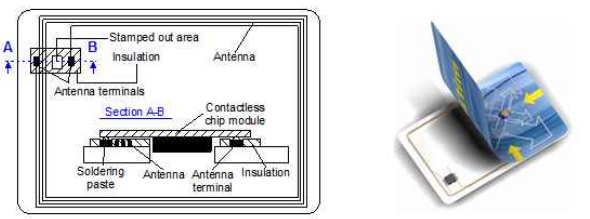

Figure 1. Plain plastic RFID card

The reader contains, at a minimum, an antenna and a scanner and is used to communicate with a tag. When an object passes by the reader, an antenna located in the reader creates a magnetic field[6]. The most atomic element of RFID is the tag. The tag contains a small integrated circuit chip that is attached to or implanted in the objects being identified as shown in Fig. 1. The integrated circuit chip contains a microprocessor, memory, and a transponder. The communication protocol between the antennas on the tag and on the reader allows the two entities to pass data back and forth[14]. The tag uses the energy created by the magnetic field for transmitting the information to the reader, which is received by the reader and then sent to the host computer[6].

3.1 RFID tag types

The most atomic element of RFID is a tag. The tag contains an antenna and a small microchip[14].

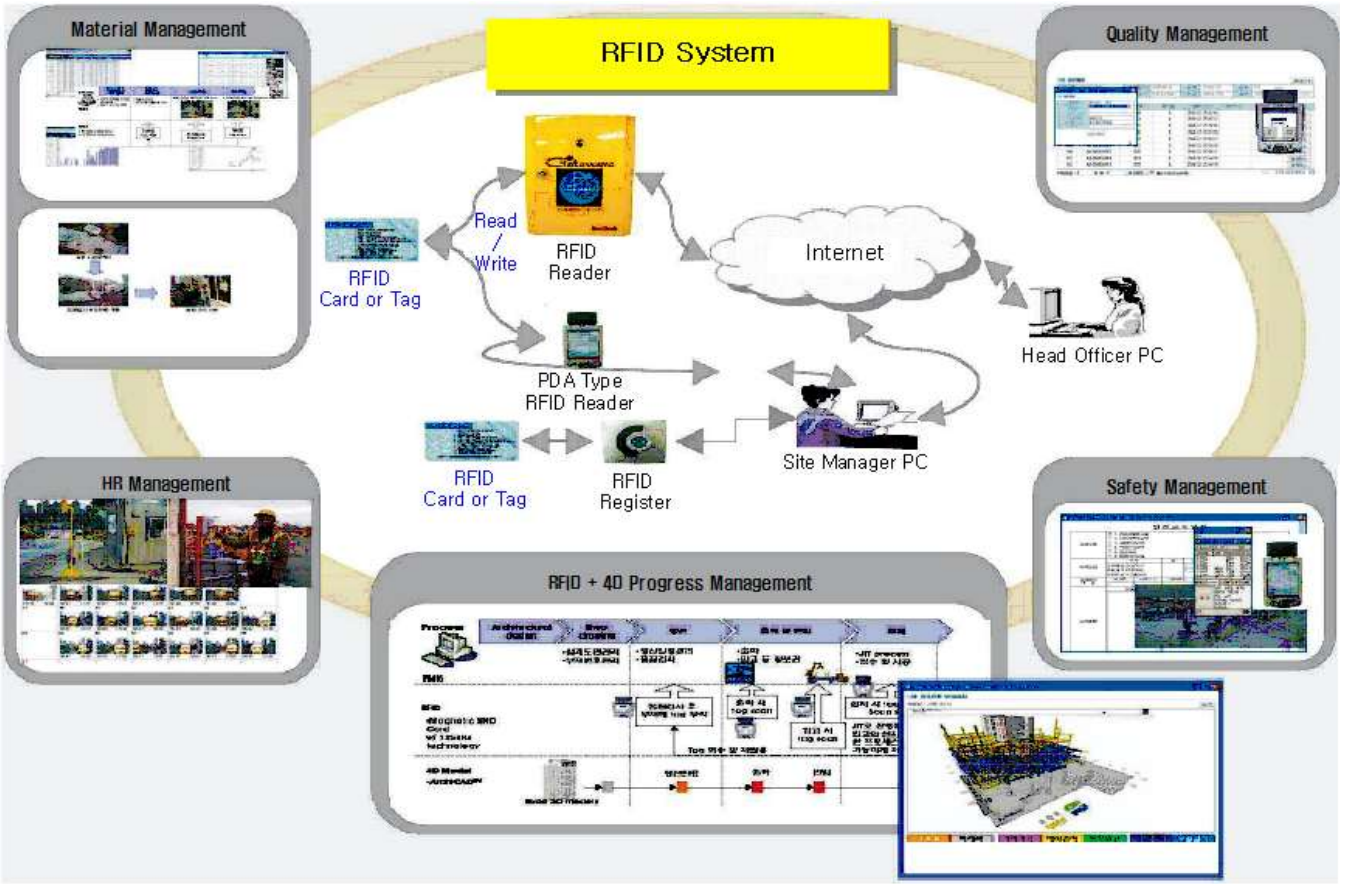

Figure 2. RFID system architecture

The small microchip is comprised a microprocessor, memory, and a transponder, its purpose is to transmit the unique identifier of tag and responsible for implementing the correct transmission algorithm. This algorithm ensures the proper time slot of the tag' s transmission and cause the tag to transmit at random interva[15].

There are varieties of RFID tags available, known as the active, passive and semi-active tags. The active tags can operate with battery power which is remained up to 10 years life span. Furthermore, active tags have a large memory capacity from 32 to 128KB, which compares to a relatively smaller memory capacity of passive RFID devices that currently varies from 128 to 256bytes[11]. However, passive tags have a long life period which is 20 years or more because it does not require a battery to operate. The power of passive tag is provided by the RF wave created. Today, passive tags are applied majority of the construction industries due to it are cheaper and made smaller than active tags. A semi-active tag is the type which is combined a characteristic of the active tag and the passive tag. This tag only battery when energized and then the battery power are returned to sleep mode. However, this tag has still a short read range when compare with an active tag. While, if the tag has temperature or chemical sensor, the battery can power and it operates exactly the same as active tag such as the part of transmission distance[15].

3.2 RFID frequency

RFID frequency is classified 4 different kinds. The most common frequency is the low frequency. It works 125KHz-135KHz, normally utilized for access control and asset tracking[16]. The high frequency that used in active tags has 0.5m read range and utilizes 13.56MHz. In addition, high frequency is commonly applied when a medium data is required[16,17]. The Ultra-High frequency which operates from 400MHz to 960MHz is used when require long read range from 1 to 5m[17]. The last frequency band which called Microwave Frequency can detect a tag from 0 to 500m using active tag, uses 2.45GHz to 5.8Hz of frequency band[17].

4. Development of the RFID+PMIS System

4.1 System architecture

The PMIS+RFID technology has been developed using Microsoft.Net and SQL server. The system architecture is designed as shown in Fig. 2. Although this research has been conducted with a focus on the use of RFID technology in the RMC truck process, the RFID technology could be used for far more work sectors. It can be used not only RMC truck process of material management, but also other sectors of construction such as quality, human resource, safety, and progress management as well. The integrated environment of developed system is used to issue invoices and assign RFID tags for the issued invoices. It manages the process data from passing at the gate of a construction site based on the process of each RMC truck. Process data are collected by stationary RFID readers and then synchronized to PMIS server automatically. The objectives of these two implementations can be able to improve the efficiency of logistics management for RMC truck process, and to verify the technical and practical feasibility of RFID application in construction industry. It can be to build a necessary and practical application strategy for RFID technology when RFID applications have been proven to be feasible as well.

The reading system for RFID tags can be different as well. In this research, stationary RFID readers installed at the gate of a construction site and are used to read a tag that comes with an invoice at a construction site. Stationary RFID readers can be used for identification of incoming and outgoing RMC trucks with the invoice. The used RFID readers at the gate of a construction site are presented as shown in Fig. 8.

Attached to the chip is the antenna, whose purpose is to absorb RF waves from the reader's signal and to send and receive data[18]. The antenna is also known as the coupling mechanism[14]. In electronics, coupling refers to the transfer of energy from one medium to another[19]. The transfer of energy is in the form of magnetic field, which is the way the tag and reader communicate. In the correct environment and proximity to an RFID tag reader, these antennas can collect enough energy to power the tag's other components without a battery[14]. Based on the type and intended use of the tag, the antenna may have many different shapes and sizes[14]. The larger the antenna, the more energy it can collect and then send back out. Larger antennas, therefore, have higher read ranges although not as high as those of active tags. Antenna shape is also important to the performance of the tag.

In this research, the tag is a plain plastic RFID card that can be used as a clip for an invoice to track the process of RMC trucks. The tag can simultaneously communicate storage and transfer locations information with the unit en route[6]. It

comes with the invoice and contains the information to a construction site. In this research, the tag do not attached directly to a RMC truck, but it is inserted with the invoice, so that RMC truck logistics and process can be tracked automatically by PMIS. The tag identification numbers are then assigned to the associated information data such as a RMC truck number, order date, quantities, and etc. as shown in Fig. 4 and 5. Information data of RMC trucks could be stored in the PMIS database server and read whenever they are needed. And it is necessary and practical to consider the reusability of RFID tags of a plain plastic RFID card type in the RMC truck application to meet the economic requirements.

4.2 Processes of autonomous data collection

Logistics and process management for monitoring RMC trucks under the integrated environment of PMIS+RFID technology were built based on the application strategy described above system architecture section. The components of the system can be varied depending on the type or characteristic of a given environment. The RFID based RMC truck process of this research is proposed as shown in Fig. 3.

The RMC truck process diagram proposed by this research begins from the checking construction information and forecasting materials and quantity for delivery to a construction site based on estimated bill of materials of a given project as shown in Fig. 3. In this stage, these properties include the identification of a process report and information of RMC trucks, and share the data information with each other, such as requested and used information, materials, and quantity. As shown in Fig. 3, the head office manager sends an invoice to a subcontractor with above mentioned information. After completing the quantity order to the subcontractor, the basic properties are exported to the PMIS server that supports logistics and process management, and the status information, received or not received order, is changed according to the status of order. In this process, the head office, the construction site, and the subcontractor can share RMC truck information in real time and streamline information exchange with appropriate decisions.

When the RMC truck enters the construction site, the process is designed such that managers need to identify the date and time on which the RMC truck passed at the gate of a construction site by touching the plain plastic RFID card invoice directly, and the information of RFID tags is assigned to the PMIS database server that considered the inspection. The invoice is issued using the PMIS, and the corresponding RFID tags are registered for each invoice. The ideal procedure would be to attach RFID tags with the invoice and to keep track of the RMC truck procedures throughout the whole process.

The process in this pouring phase is developed by considering some practical points. The construction site manager needs an easy process for controlling one by one the RMC truck. Employees of the construction site can check the process of concrete pouring and test the final quality inspection of the concrete. RMC trucks which have completed their pouring return to the plant and prepare for the next round of its delivery. As presented above, the overall process status, order, loading, delivery, pouring, and the RMC truck return, as well as the RMC truck process from a plant to a construction site was easily identified on PMIS server as shown in Fig. 3.

This interface program constantly runs during the whole process of RMC delivery, and reads and stores new tag information as soon as it is

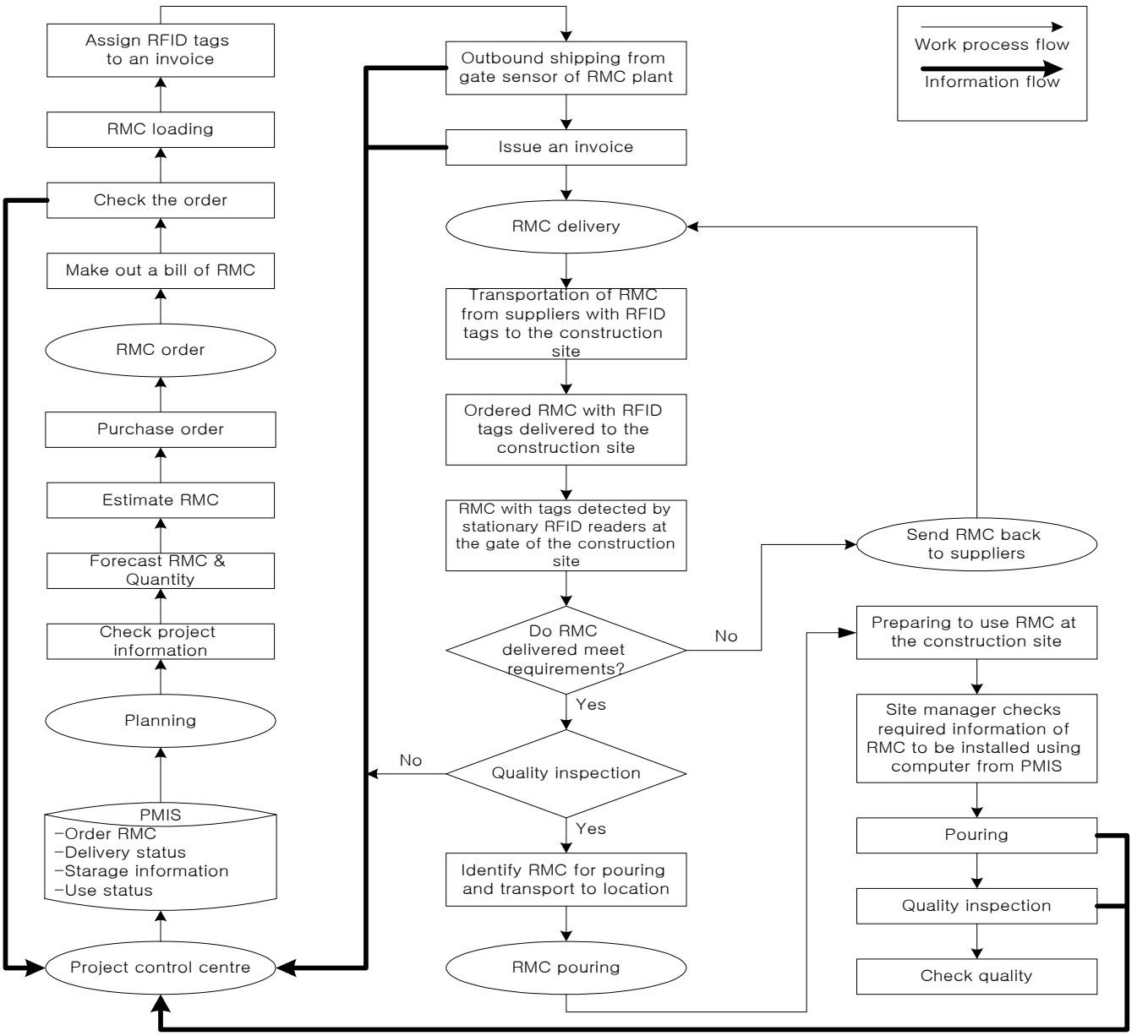

Figure 3. RMC process flow

generated.

The monitoring processes from the RMC plant to the construction site, in which developed system was applied as main technology. The registered tag identification number on the PMIS can keep track of the RMC truck and status of information whenever RMC truck pass the stationary reader installed at the gate of a construction site. In other words, when the tags attached to the stationary reader, PMIS can recognize which RMC truck has arrived and read data and then transmit its information at the same time. The time interval for order, loading, delivery, pouring, and the RMC truck return for each RMC truck can be automatically confirmed by the associated time information on the PMIS.

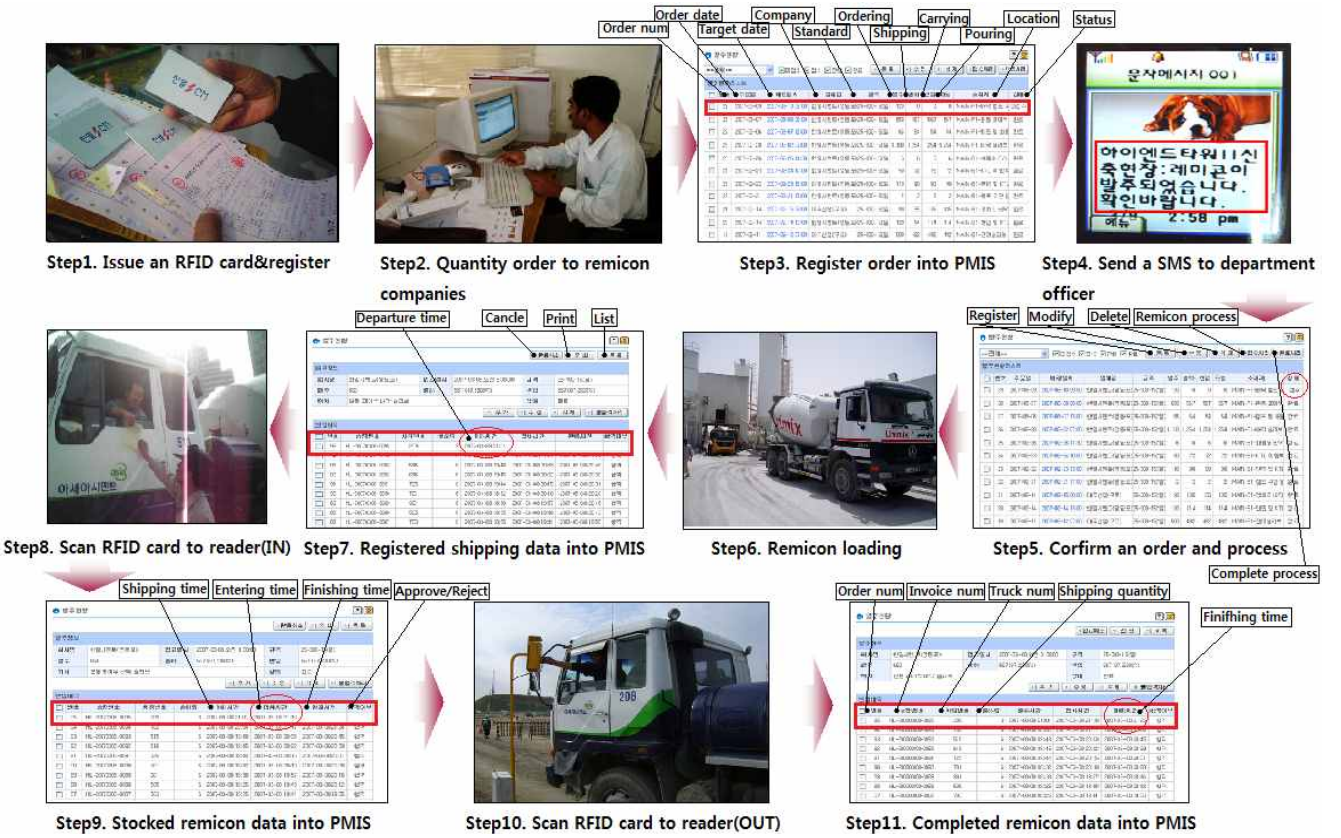

Figure 4. Monitoring procedure of PMIS+RFID system

4.3 Data transform and processing

The PMIS+RFID technology provides useful information over the whole process of a construction project. In the system monitoring process, associated project managers and engineers can obtain access to the RMC truck information on the PMIS web at the same time. In the same way, they can access information and adjust the truck interval for RMC delivery as well.

Automatic acquisition of RMC truck data requires the construction manager to develop an integrated software system part and interface system part. The software system is used by RFID technology. The status information generated during the whole process is acquired using the RFID technology components in the wired or wireless internet. The interface system part, PMIS, is developed in a web environment. The PMIS is connected to the internet server and can recognize each stationary reader using its IP address. Thus, information data from all stationary readers are saved in the database server, and the status of a RMC truck process can be checked anywhere at anytime using PMIS. It was developed to provide status information in real time through the internet based on PMIS. The PMIS should update the RMC truck process data and allow for head officers, site managers, and subcontractors to access the data through the wired or wireless internet. The interface system of the PMIS is connected to the plant system at the RMC plant as well. The system could receive information data of RMC trucks automatically. It can there easily be adopted for use during the construction process.

They monitor the process of the RMC truck anywhere at anytime by visual inspection and make

decisions on delivery interval as well. By contrast, the PMIS generates a variety of information data on RMC truck process. The PMIS is a combination of different technologies that should be tested on actual construction site to verify its effectiveness. The building project was selected as a case study to test the feasibility of developed system. Using these data, associated project managers can check the three time points, shipping, entering, and finishing, as shown in Fig. 6.

5. Case Study

According to recent report that it is known that up to 70 % of the overall construction cost is direct cost relating to material, manpower, and machinery[20]. The purpose of the case study was to test the applicability in real-world of the PMIS for monitoring and controlling with RFID technology. Therefore, this case study describes RFID+PMIS system applications focus on RMC process management.

In this research, 914 MHz RFID tags with passive type were chosen and the tag is a plain plastic RFID card that can be used as a clip. Communication technology has advanced to the associated project of managers. Site engineers can directly access the PMIS server from anywhere at any time if they can access the internet using PCs, PDAs, and mobile phones. The decision was based on reviews of technological feasibility, field testing.

5.1 RMC management process

Suggestion procedure in this study is shown Fig. 3. The instruments of information collection were used RFID tag, RFID reader, and PMIS. RFID tag was attached personal ID card and RFID reader was located on the gate.

At each step of the RMC truck process, the tag data were read successfully to generate the associated all of information. After checking the status of the order, RMC trucks departed from plant to the construction site with an invoice. When RMC trucks arrived at the construction site, the RFID invoices that come with RMC trucks were read by using a stationary reader installed at the gate.

The process time of RMC truck was identified for receipt of truck information at the construction site automatically by RFID tag. The order information was confirmed on PMIS screen such as information of order number, order date, target date, company, standard, ordering, shipping, returning, pouring, location, and status of receive, as shown in Fig. 4 and 5. The status information of last column of PMIS screen associated to logistics and process, which is used to change its process status from 'not receive' to 'received' when the process information was registered automatically. As soon as make sure the update of the PMIS, the information of RMC truck was synchronized to the PMIS server to change the status of the corresponding information to show 'received'.

The tag associated RMC truck data such as order number, invoice number, and truck number are automatically entered into the PMIS before the beginning of RMC delivery. When a RMC truck passes a read point where a stationary reader is installed at the gate, the reader detects RF signals. And, RFID invoice can be automatically sent upon arrival at the construction site. The reader then transmits information reading for RMC truck to the PMIS server through the wired or wireless internet. The transmitted time reading is stored into the PMIS database. Three times associated points, shipping, entering, and finishing, are presented on PMIS at the construction site and required to determine other associated data: (1) estimated time from shipping to entering at construction site; (2) estimated time to

complete the pouring; (3) concrete shipping quantity; and (4) the result of concrete quality test. RFID tags which had been assigned identification numbers were attached with an invoice. For example, shipping time at the plant was calculated based on the average differences between quality inspection and shipping dates collected through previous daily report and PMIS. Waiting time of RMC trucks is approximately calculated based on between entering time and finishing time. It is an indication of the efficiency of the concrete pouring operation. A longer waiting time can adversely affect quality, but it also implies that the pouring work can be conducted without interruption[21]. The RMC plant personnel can present this information on RMC truck process in the PMIS environment, and decide whether or not to adjust the RMC truck intervals or the number of RMC trucks.

5.2 Monitor method of PMIS

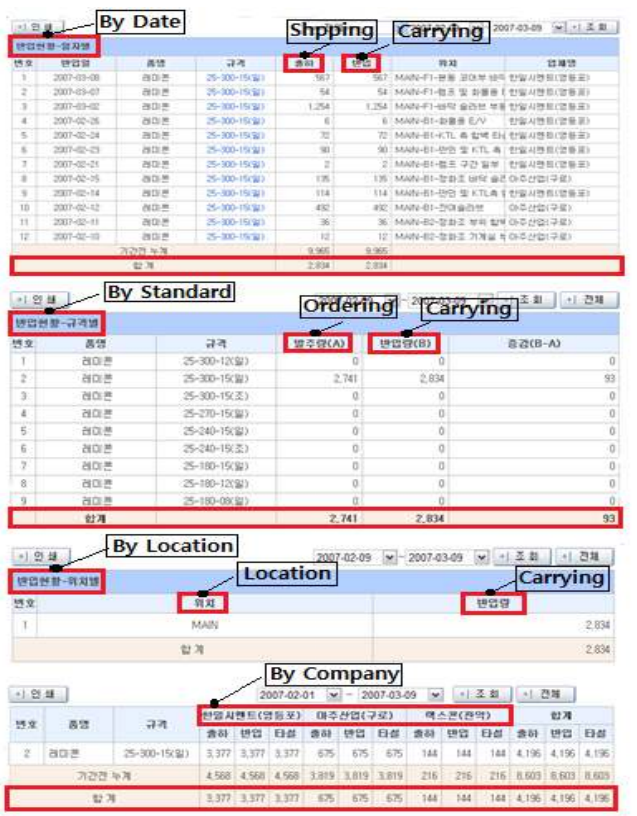

Figure 5. RMC process present condition of PMIS

The PMIS provided the detailed information required for monitoring and controlling using RFID tag data. Collected data via RFID ID card scanning is processed automatically for various methods special day, term of attendance, and present condition of attendance through the PMIS system. The receipt information of each RMC truck is reflected to the PMIS server by synchronization with a PC. Fig. 5 shows information are extracted and stored by date, standard, location, and company in a PMIS database server. This measurement provides to fountainhead data which can grasp productivity of construction activity and result quantity. And, the effective reuse method of RFID tags is needed to save adoption cost. The tags are collected and sent back to the plant, and each tag is assigned to the newly renewed information on the PMIS. The RFID tags are reused to save costs.

5.3 Result and discussion

The test results indicate that the application RFID+PMIS system in construction site in South Korea has brought magnificent effects. It is an indication of the efficiency of the concrete pouring operation. A longer waiting time can adversely affect quality, but it also implies that the pouring work can be conducted without interruption. Also, in the RMC process case, five minutes of time saving effect was confirmed averagely per one RMC truck rather than conventional process without frame work. The time saving reduction parts were classified three different sectors which are the part of waiting time for the entrance and exit time checking by field representative and the part of waiting time for the pouring location checking. Therefore, the construction site where needs 300 m^3 pouring (50 RMC trucks) per day can be reduced total 250 minutes. Moreover, this time saving is

related to the labour cost saving. Normally, five labours are necessary per one RMC truck in the pouring stage and labour cost per person was surveyed 10,000 won per an hour thus, total 50,000 won of labour cost was spending per an hour. Therefore, in the construction site where needs 300 m^3 pouring (50 RMC trucks) per day case, it is possibility to reduce total 208,000 won of labour cost and in the night work case, total 312,000 won of labour cost can be saved due to the 50 % of labour cost is increased. This night work labour cost saving is similar with the cost of one RMC truck (24 N/m^2) that is 360,000 won. Additionally, the above mentioned result is only surveyed in terms of RMC truck process thus, enhancement effect of time, equipment and a waste of an element saving will be increased in real world construction site because more kinds of logistic vehicles are entering and waiting time is more delayed.

6. Conclusion and Recommendations

This research proposed the PMIS+RFID technology integrated environment for the logistics and process of the RMC truck item in a construction project. The new developed system combines RFID technology with the PMIS to provide RMC truck operations. RFID technology provides an opportunity to meet the current needs for communicating RMC truck information on PMIS database, and accessing this information on-demand. The PMIS was developed to demonstrate its feasibility as well. The PMIS+RFID technology has been automatically implemented and has shown process information about the RMC truck and the overall status information about it, both quickly and accurately. In addition, the process could have been performed more quickly because the time spent for waiting and loading RMC trucks was reduced. During the real-world case study, the PMIS generate information on estimated time information, concrete pour quantity, and the result of concrete quality test. Construction companies can save time, money, and effort with effective use of RFID technology for several operational procedures. The ideal process time was expected to be the same as the process time for the current developed system.

However, various problems were encountered during the initial preparation of the PMIS+RFID implementation. Most of involved participants lacked to understand whole process through PMIS and report them in the RFID technology which the majority of them have never used before. Accordingly, participants were continually monitored and educated by field managers. In spite of initial preparation, involved participants recognized that the application of enabled to control more accurate logistics and process. This research shows the possibility of construction industry associated project of managers and engineers with information about enhancing their communication using PMIS+RFID technology. This could lead to the reduction of risks and schedule overrun by identifying production and process information in advance and by monitoring. Even if it is needed the time for setting up initial preparation, the PMIS+RFID technology enabled the manager to make a more efficient decision at the construction site on the orders for RMC truck operations. As built PMIS can effectively control logistics and process, applying the optimum RFID technology to each construction project, and this research need to study out solution in order to overcome RFID technology limitation through development of specification counter proposal about delicate materials of the RFID technology application.

Additionally, the above mentioned result has fluctuation depends on the size of field, work duration, and a number of workers. Therefore, in the large scale work place case, the width of productivity, efficiency and saving cost are increased while, in a smaller scale case, the effect is reduced due to the part of initial cost of RFID+PMIS system is occurred. The developed system will be necessary to accelerate technological development associated to tag performance for more applications in construction. If the data storage capacities of the tags are sufficient to store a large amount of data, a more flexible and powerful PMIS+RFID technology can be applied for construction. In addition, the PMIS must be further extended to become a part of construction to streamline data control during the material delivery management. This makes PMIS+RFID technology system attractive to the other construction application sectors, quality, human resource, safety, and progress management as well. PMIS+RFID technology can also be further developed into a decision support system to enhance the efficiency of material delivery management in construction projects.

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